University at Buffalo
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Language Error in Aviation Maintenance

Year 2 Interim Report

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January 2004

Prepared for:

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Executive Summary

In a 2001 report to the Secretary of Transportation by the Aircraft Repair and Maintenance Advisory Committee, the FAA raised many issues concerning outsourcing of maintenance to foreign repair stations in considering changes to the domestic and foreign FAR Part 145. They recommended that:

> *"The FAA should establish a method for determining whether language barriers result in maintenance deficiencies."*

This project is a direct response to these concerns that non-native English speakers, in repair stations in the USA and abroad, may be prone to an increased error rate that could potentially affect airworthiness.

The first two years of this project developed seven scenarios of language error based on visits to sites in the USA and UK. In these two years the team also provided a model for these unique communication errors, based on the communications literature and analysis of several databases. These included the National Aeronautical Space Administration (NASA) / Aviation Safety Reporting System (ASRS) error database and responses to a questionnaire on language skills provided by a major manufacturer. Our analyses showed that language skill varied (as expected) by world region, and that not all sites with lower language skills translated documents into the native language.

In Year 2 we have taken the language error scenarios developed in Year 1, and used them as the basis for designing questionnaires to determine the frequency of these scenarios, how they can arise and what interventions are pursued to prevent the errors from propagating through the system. As we begin our data collection, we will use these questionnaires at each site we visit to build a comprehensive database for analysis in Year 3.

The Interventions experiment has also been designed and tested on two groups of participants: English-speaking maintenance personnel and Chinese speaking engineering graduate students. Neither is the final target group, but the methodology has been verified before on-site data collection. The main comprehension task takes less than half an hour to complete, while the other measures such as the English reading ability test and the rating scales together take another 15 minutes or so. Because many people can be tested together, we can be efficient in data collection at each site. At this stage, the small sample sizes are precluding any significant effects, so these pilot studies are being used for testing the methodology, training the experimenters and providing an English-speaking baseline condition.

After having had one data collection visit cancelled, and encountering some difficulties with other foreign sites post "9-11," we are now planning data collection using our contacts in China and Taiwan. Data collection at these sites will take place in March and April 2004, with any other sites coming in Summer 2004.

1.0   Development of a Classification Scheme for Human Language Errors in Maintenance

Based on findings from Year 1 focus groups on language errors in aviation maintenance (Drury and Ma, 2003),[1] a booklet of questionnaires were designed to survey the foreign Maintenance (MROs) we plan to visit. Potential participants include people who deal with safety or quality at the site, including supervisors, managers, quality assurance and engineering personnel. The questionnaires ask if they recognize any of the language error patterns we have developed. We also ask about how such language difficulties were resolved. The questionnaire takes about 15-20 minutes to complete and multiple people can be tested together. Seven scenarios are included:

> **Scenario 1:** "The Mechanic (AMT) or Inspector was not able to communication verbally to the level required for adequate performance."
> **Scenario 2:** "The Mechanic (AMT) or Inspector and the person they were talking to did not realize that the other had limited English ability."
> **Scenario 3:** "Native English speakers with different regional accents did not understand each others' communications."
> **Scenario 4:** "The mechanic (AMT) or Inspector did not understand a safety announcement over the Public Address (PA) system."
> **Scenario 5:** "The Mechanic (AMT) or Inspector did not fully understand a safety placard."
> **Scenario 6:** "The Mechanic (AMT) or Inspector did not fully understand documentation in English, for example a Work Card or Manual."
> **Scenario 7:** "The Mechanic (AMT) or Inspector did not fully understand a document translated from another language to their native language."

1.1   Measuring Frequency of Language Errors

For each scenario, the questionnaires inquire about *existence*, *frequency of encountering*, and *last time encountered*. For the most recent encounter (if there was one), a series of factors that can make the type of error more likely are listed to be checked:

1. The task is complex
2. The task instructions are complex
3. The communication channel, e.g. radio or PA interferes with good communication
4. Time pressure prevents the mechanic (AMT) or inspector from asking other people for help
5. The mechanic (AMT) or inspector has inadequate written English ability
6. The mechanic (AMT) or inspector has inadequate verbal English ability
7. The mechanic (AMT) or inspector reverts to their native language under stress
8. The mechanic (AMT) or inspector is unwilling to expose their lack of English
9. Time pressure makes the mechanic (AMT) or inspector hurry

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To probe potential interventions, we next ask for factors that help prevent each scenario:

1. The document is translated into the native language of the mechanic (AMT) or inspector.
2. The document uses terminology consistent with other documents.
3. The document follows good design practice.
4. The mechanic (AMT) or inspector uses the aircraft as a communication device, for example to show the area to be inspected.
5. The mechanic (AMT) or inspector is familiar with this particular job.
6. The mechanic (AMT) or inspector has taken and passed a comprehension tests.
7. The mechanic (AMT) or inspector was certified for that specific job.
8. There is a translator available to help the mechanic (AMT) or inspector.
9. Jobs are assigned to the mechanic (AMT) or inspector to job based on English.
10. The mechanic (AMT) or inspector is teamed with a native English speaker to perform the job.

Finally, the questionnaires inventory the cues or hints on how these types of language errors can be discovered and prevented:

1. The mechanic (AMT) or inspector appeared perplexed.
2. The mechanic (AMT) or inspector agreed with everything that was said.
3. The mechanic (AMT) or inspector asked for assistance or clarification.
4. The mechanic (AMT) or inspector closed access prematurely (i.e. before buyback).
5. The physical error resulting from the language error was detected.
6. The mechanic (AMT) or inspector did not understand inspector's questions at buy-back.

2.0   Measuring Intervention Effectiveness

To test for how potential documentation errors can be reduced, we are measuring the effectiveness of document comprehension. We are collecting comprehension data at each foreign MRO site using comprehension tests of task cards to evaluate the effectiveness of each intervention strategy (i.e. Simplified English). The methodology was validated in our previous research (e.g. Chervak, Drury and Ouellette, 1996;[2] Drury, Wenner and Kritkausky, 1999).[3] We selected two task cards, one "easy" and one "difficult", from four task cards used in Chervak, Drury and Ouellette (1996)'s[2] research. One task card (labeled SUNYAir 290) addresses "Functionally Check Hydraulic System L/R/C Reservoir Pressurization Check Valve for Proper Operation," while the other task card (SUNYAir 380) addresses "Change Potable Water Engine Bleed Air Filter Element." The complexity of these task cards was evaluated by Boeing computational linguists and University of Washington technical communications researchers considering four factors in their Non-Simplified English (SE) versions (**Table 1**). A task difficulty rating of each task card by an experienced engineer was also used for guidance.

Task Card	Complexity	Word Count	Words per Sentence	Percentage Passive	Flesch-Kinkaid
SUNYAir N380	Easy	254	8	3	8.6
SUNYAir N290	Difficult	491	17	25	10.4

Table 1. Characteristics of the Non-SE Versions of Two Task Cards

Both of the task cards were then prepared in AECMA Simplified English versions, which were critiqued by Boeing, University of Washington, and the AIAA Simplified English Committee experts (Chervak, Drury and Ouellette, 1996).[2] In addition to be written in Simplified English, other interventions tested include providing a language glossary, using a person who speaks better English as a "coach", or even using fully translated versions of the task cards. One task card will be given to participants (mechanics, inspectors, supervisors) with a 10-item questionnaire to test comprehension. We will also provide a short test of English ability to help us in the analysis. Our chosen reading ability test is the Accuracy Level Test (Carver, 1987).[4]

2.1   Experimental Design

Our study is a three factor factorial design with the participants nested under the three factors. The factors are:

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2.1.1 Independent Variables

1. Task Card Complexity (Easy vs. Difficult)
2. Document Language (Simplified English vs. Non-simplified English)
3. Interventions (none, glossary, full translation, tutoring, glossary & tutoring)

2.1.2 Dependent Variables

1. Performance measures on 10-item comprehension questionnaire:
2. Completion time
3. Accuracy
4. Task cards rating: 15 rating scales scores
5. Style of using interventions (i.e. glossary, and/or tutoring)
6. Possible performance predictors or covariates:
   a. English Reading Grade Level (i.e. Accuracy Level Test)
   b. Experience as an aviation mechanic
   c. Job category
   d. Native language

2.2 Procedure

The testing will take place at available conference rooms at the foreign MROs. Each participant is given verbal instructions for completing a demographic questionnaire and the Accuracy Level Test. Participants are randomly given one of the 4 possible task cards, its comprehension questionnaire (20 questions) and a set of task card rating scales (15 scales). Depending on the intervention condition, a glossary in his/her native language, a tutor, and a combination of a glossary and a tutor is provided. For the full translation intervention, only a fully translated task card in his/her native language is provided but not the original English version. Correspondingly, the comprehension questionnaire is also translated into the native language, and the participant is asked to answer the questionnaire in his/her native language. Distribution of task cards at each MRO is in rotating order with a new starting point. The rating scales are adapted from the evaluation scales used by Patel et al (1994),[5] covering ease of use of the task cards and attached graphics, the simplicity of the English used, and finally an overall rating on usability of the task cards. All are 9-point scales (0 to 8) anchored at each end with an appropriate adjective, and with their midpoints located at a scale value of 4.

In a task card comprehension questionnaire, generally a question concerning specific technical information is followed by a question asking where this information is located in the task card. The questions demanded a short answer, a "fill in the blank," or a multiple choice. Both SE and non-SE versions of each task card have the same comprehension questionnaire. In some cases, different words are used in SE and non-SE versions of task cards to refer to the same object, so that, a neutral word with similar meaning is used in the comprehension questionnaire to prevent bias. For example, in the SE version, a term "Do-Not-Operate *Tag*" was used to indicate a card that was placed on

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an inoperative control lever, whereas in the non-SE version the term "Do-Not-Operate *Identifier*" was used. In the questionnaire, questions regarding these cards used the term "Do-Not-Operate *Marker*."

This study takes a total of about one hour.

2.3   Material Development for Field Data Collection

There are several reasons to collect data from MROs located in Asia, especially China.

2.3.1   Increasing Outsourcing to That Area

The Asia-Pacific region is poised to be one of strongest growth engines for the foreseeable future for the maintenance, repair and overhaul industry (*Overhaul & Maintenance*, 2002).[6] U.S. and European airlines continue to ship widebody aircraft to East Asia to take advantage of low labor costs. In addition, East Asia continues to be a hotspot for Western Original Equipment Manufactures (OEMs) and MRO companies looking to enter or strengthen their presence in the market through joint ventures and partnerships—especially for engine overhaul. The Top 10 Asian airframe MRO companies (based on annual labor man-hours, *Aviation Week's Show News online*, 2002) are:

> No.1 HongKong Aircraft Engineering Co. Ltd. (HAECO), Hong Kong, China
> No. 2 Singapore Airline Engineering Co. (SIA Engineering), Singapore
> No. 3 Air New Zealand Engineering Services, New Zealand
> No. 4 Aircraft Maintenance Engineering Co. (AMECO), Beijing, China
> No.5 Singapore Technologies Aviation Service Co. (SASCO), Singapore
> No. 6 Quntas Airways, Australia
> No.7 Guangzhou Aircraft Engineering Co. Ltd. (CAMECO), Guangzhou, China
> No.8 Japan Airlines, Japan
> No.9 Korean Airlines, Korea
> No.10 Taikoo (Xiamen) Aircraft Engineering Co. (TAECO), Xiamen, China

Almost half of the top 10 Asian MROs are located in China. According to *Aviation Week & Space Technology*, "the Civil Aviation Administration of China (CAAC) is confident that despite the downturn in the global airline industry, more maintenance, repair and overhaul (MRO) joint venture companies will be set up with Chinese airlines within the next two years" (Dennis, 2002).[7]

2.3   From Survey Data, the Language Problem is an Issue in Asia

In Year 2, an international corporation surveyed a large number of airlines throughout the world concerning their use of English and other languages in flight operations and maintenance operations. We were given access to this data and analyzed the maintenance portion of it (Drury and Ma, 2003).[8] We found Asia has about 30% of users with very limited English speaking ability, another 40% were able to conduct simple conversations; about 40% of the users were able to work effectively with written maintenance/inspection related documents, and another 15% had very little English reading ability. Compared

with North America and Europe, Asia has a much smaller base of English using mechanics. The airlines cope with any potential problems using a number of means, including document translation, and conducting training and meetings in native languages. Translation of documents was used for less than half the time in Asia. It does not appear to be the preferred response strategy to any language mismatch issues, even where English reading and speaking ability is low. In addition, in Asia, meetings and training are often conducted in the native languages, which may be a mismatch to documentation used in the same task.

2.4   Interventions

2.4.1   Translation

The first intervention we want to provide non-native English speaking users is "full translation of task card." The following packet of data collection material was translated into mandarin Chinese:

1. SUNYAir 380 task card (in non-simplified English, as N380)
2. SUNYAir 380 task card (in AECMA simplified English, as S380)
3. SUNYAir 290 task card (in non-simplified English, as N290)
4. SUNYAir 290 task card (in AECMA simplified English, as S290)
5. Comprehension Questionnaire for task card 380
6. Comprehension Questionnaire for task card 290
7. Rating Scale for task card
8. Demographic Data Sheet
9. Inform Consent
10. Debriefing

The translation process took place in two steps. A native Chinese research assistant (9-yr as engineering major) who is very familiar with the task cards took a lead in translating the packet. A large amount of technical references and language references were consulted. The principal investigator and other domain experts (e.g. native Chinese mechanical engineers in Department of Aerospace and Mechanical Engineering at University at Buffalo) were consulted on the technical details (e.g. lockwire). Then both translated and original packets of data collection material were submitted to a retired professor from Department of Avionics, Civil Aviation University of China for a review.

2.4.2.   Glossary

The second intervention we want to test is providing participants a Glossary between English and their native language. We developed an English/Chinese glossary for each task card (N380, S380, N290, and S290). We had two native English speaking engineering graduates and two native Chinese engineering graduates read through all the task cards and circle all the words/phrases/sentences they did not comprehend, or even were slightly not sure. We developed a Glossary to be as comprehensive as possible, including nouns, verbs, adjective initials, etc.

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Task Card	Noun	Verb	Adjective	Abbreviation
N380	17	7	3	0
S380	16	11	2	1
N290	25	11	3	2
S290	25	12	1	2

Table 2. Number of Words by Category in Glossary

2.4.3. Bilingual Coaching Procedures

A person at foreign MROs who speaks better English will be recruited as a "coach." After each hosting site recommends a couple of candidates with their consent, we will test their English ability individually using both the English reading Accuracy Level Test and directly conversing with them. The experimenters will provide the selected "coach" all four task cards, their glossaries and Chinese versions. The "coach" will be specifically instructed to help fellow participants to understand task card contents but not answering the questionnaires for them or giving any hint. Although the "coach" will be an aviation maintenance/inspection domain expert, he/she will give adequate time to familiarize him/herself with our task cards and practice the "coaching." The experimenters will monitor the tutoring process closely. A native Chinese experimenter is ready to fill in anytime if it is necessary. In fact, she acted as a "coach" in our pilot test using native Chinese Engineering students.

2.5 Pilot Test of Methodology Using Native Chinese Engineering Students

From December 2003 to January 2004, we conducted a pilot test of our methodology before actually collecting data in foreign MROs in China. Twenty native Chinese engineering students were recruited from graduate student pool at University at Buffalo.

Air China Inc., one of the largest Chinese airlines, required its maintenance and inspection personnel "have the English ability to be able to read and comprehend any work-related manufacture's brochure and maintenance manual." However, we do not have statistics on English ability of aviation mechanics and inspectors' at Chinese MROs. We assume that a Chinese graduate student majors in Engineering in the United States possess more knowledge and higher ability in using English language in general, and in order to decrease the gap between these two groups, we required that student participants arrived in the United States no earlier than May, 2003 to be eligible in participating this experiment.

The 20 participants consisted of 9 males and 11 females, with a mean age of 25.5 (SD = 2.3). **Figure 1** shows the distribution of scores on our chosen reading ability test, the Accuracy Level Test (Carver, 1987).[4] This ten-minute limited vocabulary test measured the reading level of a participant as an equivalent grade level. The test has high reliability (0.91) measured on college students and has a high validity (0.77 to 0.84) when

compared to a longer standard reading test (the Nelson-Denny Reading Test). Carver (1987)[4] provides data on two appropriate comparison groups for this test: freshmen undergraduate and beginning graduate students, and both groups were native English speakers. The mean score of our sample (9.9, SD = 2.1) was significantly lower than either US college freshmen (12.5) with T = -5.60, p < 0.001 or either US graduate students (14.3; T = -9.01, p< 0.001). In Year One, we had fifteen native English speaking participants from the MROs in the UK and the US (mean = 14.1, SD = 1.4), and their reading level was typical of an educated adult group, i.e. above college freshmen but a little below graduate students.
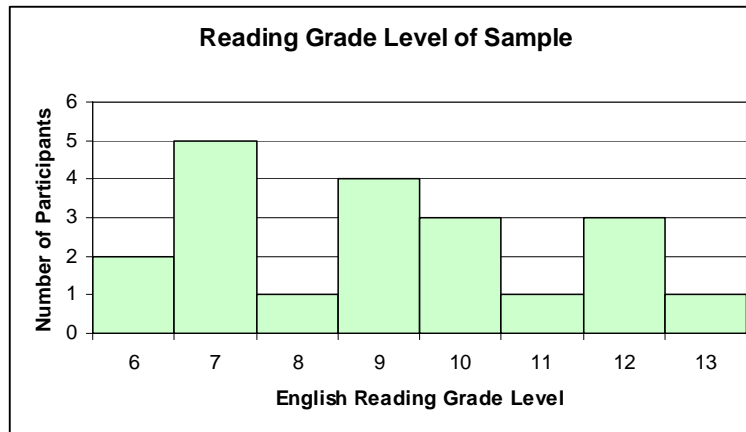
Figure 1. Reading Level Results for 20 Student Participant Sample

2.5.1 Pilot Test Results

2.5.1.1 Performance Measures (comprehension questionnaire time & accuracy)

For our pilot test group, there are three possible individual variables that may affect performance: reading level score, years of learning English, and years as Engineering major. These could be useful covariates in the analysis of main factors by reducing the expected variability between individual participants. An inter-correlation matrix of these revealed that only "Years of learning English" was significantly correlated with the time to complete task card comprehension questionnaire (R = 0.47, p = 0.039), but no measures were related to accuracy. We decided to consider one covariate: "year of learning English."

We used GLM 3-factor ANOVAs on each performance variable with the above covariate but found no statistical significance. This was probably due to our, so far, very small data sample (**Table 3**) and the fact that all our 20 participants had no domain experience.

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		Task Card Complexity-Document Language			
		Easy-SE	**Difficult-SE**	**Easy-NE**	**Difficult-NE**
Interventions	**None**	1	1	1	1
	Full Translation	1	1	1	1
	Glossary	1	1	1	1
	Tutoring	1	1	1	1
	Glossary + Tutoring	1	1	1	1

Table 3. Small Data Sample

During Year 1 and Year 2 we collected data from 15 participants in MROs in the UK and the US. All were native English speakers and were tested on both Easy and Difficult Task Cards under non-SE and SE conditions. If we include the first 15 participants in the "None Intervention" condition, then we get:

		Task Card Complexity-Document Language			
		Easy-SE	**Difficult-SE**	**Easy-NE**	**Difficult-NE**
Interventions	**None**	5	4	4	5
	Full Translation	1	1	1	1
	Glossary	1	1	1	1
	Tutoring	1	1	1	1
	Glossary + Tutoring	1	1	1	1

Table 4. Small, Unbalanced Data Sample

An inter-correlation matrix on this combined data showed that Reading Grade Level became significantly correlated with the accuracy of task card comprehension questionnaire ($R = -0.38$, $p = 0.029$). The participants' accuracy and time in completing the task card comprehension questionnaire were significantly and negatively correlated (correlation coefficient = -0.396, $p = 0.018$): the participants tended to be either "faster--more accurate" or "slower--less accurate," as shown in **Figure 2**:
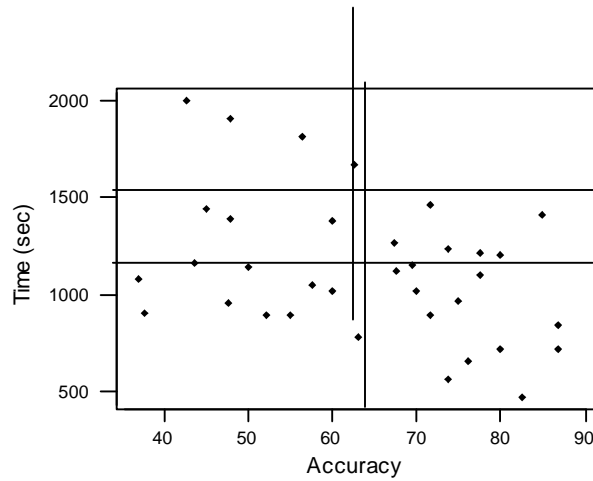
Figure 2. Time × Accuracy Plot (Mean Time = 1129 s, Mean Accuracy = 64%)

2.5.1.2 Rating Scale Analyses

There were few significant effects noted in the GLM ANOVAs for the rating scale scores. **Table 5** summarizes significance for main factors, their interaction, and covariates using only the native Chinese-speaking sample (n = 20).

Note that most of the significance is for the covariate. This means that the primary determinant of judged readability is individual difference between participants.

When the 15 UK and US participants are included, the significance levels change (**Table 6**), but still the mot significant results occur in the covariate column. However, there are now 8 significant effects out of 105 possible tests for the 7 factors and 15 measures. It is suspected that this level of significance reflects only inflated α levels rather than real effects.

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Measure	Main Factors and Their Interaction						Covariates
	Inter	**Diff**	**SNE**	**Inter x Diff**	**Inter x SNE**	**Diff x SNE**	**LearnEng(yr)**
1. Readability of text	N.S.	N.S.	N.S.	N.S.	N.S.	P=.034*	P=.02*
2. Continuity of information flow	P=.063	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
3. Ease of information location	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
4. Chance of missing information	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
5. Ease of understanding	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.062
6. Ease of location on aircraft	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.048*
7. Ease of relating figure numbers	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
8. Amount of information provided	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
9. Ease of readability of attachments	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
10. Relating graphics to aircraft structure	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
11. Consistency of presentation	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
12. Compatibility with attachments	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
13. Amount of graphics provided	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
14. Simplicity of English used	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
15. Overall ease of usability of w/c	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.048*

Table 5. Significance Levels of Main factors and Covariates for Rating Scale Data
(* significant at 0.05)

Measure	Main Factors and Their Interaction							Covariates
	Inter	**Diff**	**SNE**	**Inter x Diff**	**Inter x SNE**	**Diff x SNE**	**Inter x Diff x SNE**	**Read**
1. Readability of text	N.S.	N.S.	N.S.	P=.037*	N.S.	N.S.	P=.029*	N.S.
2. Continuity of information flow	P=.039*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
3. Ease of information location	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
4. Chance of missing information	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.068	P=.035*
5. Ease of understanding	N.S.	P=.05*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
6. Ease of location on aircraft	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.031*
7. Ease of relating figure numbers	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
8. Amount of information provided	N.S.	N.S.	N.S.	P=.06	N.S.	N.S.	N.S.	N.S.
9. Ease of readability of attachments	N.S.	N.S.	N.S.	N.S.	N.S.	P=.027*	N.S.	N.S.
10. Relating graphics to aircraft structure	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
11. Consistency of presentation	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.033*
12. Compatibility with attachments	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	P=.021*
13. Amount of graphics provided	N.S.	P=.048*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
14. Simplicity of English used	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
15. Overall ease of usability of w/c	N.S.	N.S.	N.S.	N.S.	N.S.	P=.020*	P=.032*	N.S.

Table 6. Significance Levels of Main factors and Covariates for Rating Scale Data
(* significant at 0.05)

According to our observations, most of the student participants did not utilize the interventions of glossary, tutoring, or the combination of the above two as much as we expected. After the experiment, the native Chinese experimenter asked them why they did not utilize the resources. The participants agreed that: "although we do not understand some words, even a sentence here and there, we are still able to answer the comprehension questionnaire; clarifying meaning of all details may not necessarily improve our performance, but it will take much longer to finish the task." In fact, this makes sense as all of the international students who apply for graduate school in the United States need to submit their scores on Test of English as a Foreign Language (TOEFL), and Graduate Record Examination (GRE). For non-native English speakers, in order to achieve better scores in TOEFL and GRE-Verbal tests in limited time, a key factor is the ability to figure out unknown words, phrases, even sentences in context. This is a common consensus by non native English speaking students who have gone through this process.

In addition to participants' feedback collected by the task card rating scale, a couple of participants made comments to the experimenter on the figures attached with each task card. They said they would prefer to have a small figure accompanying each main maintenance/inspection step rather than having all the figures as an attachment at the end of task card, because in that way, their comprehension of the task card could be reassured by the figures, and also they would perform faster without flipping back and forth. None of the 15 native English speaking AMT participants made comments like this, which might be partially because they have adequate domain knowledge and skills, and partially because they are used to look-alike standard maintenance/inspection task card provided by the manufactures.

3.0 Planned Data Collection Visits

In August 2003 we had arranged to visit Seoul, South Korea to collect data at two site and present papers at the International Ergonomics Association Triennial Congress. However, two days before departure, the sites cancelled their cooperation. We had in fact translated all materials into Korean, but were in the end unable to collect any data there. This led to our contacting China and Taiwan and translating the documents into Mandarin as noted earlier.

3.1 China

Five sites have been selected in China, in cooperation with a local professor who has good aircraft maintenance contacts. These are as follows:

3.1.1 Aircraft Maintenance and Engineering Corporation: Location--Beijing

Aircraft Maintenance and Engineering Corporation (AMECO), located in Beijing Capital Airport, is a joint venture between Air China and Lufthansa. AMECO is the leading MRO provider in China and one of the biggest in Asia. It is the first enterprise in China Civil Aviation that holds certificates approved by CAAC, FAA, and JAA. In 1996, AMECO was also awarded ISO 9002 certification. The main business of AMECO is to perform maintenance, repair and overhaul of airframe, engine, component work, and painting. AMECO provides line maintenance to 24 international airlines and more than 48 domestic airlines (including branches). It also offers engineering support, training services and material supply.

AMECO stations its representatives in Shanghai, Guangzhou and 18 countries and regions to provide line maintenance services for Air China and other domestic and foreign airlines.

3.1.2 The Shanghai Aircraft Maintenance Base & Shanghai Airlines: Location--Shanghai

The Shanghai Aircraft Maintenance Base, a subsidiary of China Eastern, the Base has a maintenance division that repairs foreign-made and domestic aircraft. The Base can perform D and 2D checks on the MD-82; engine maintenance for TAY-650 and CFM 56 engines; B2 grade maintenance work can be performed on the CF6-80C2 and the JT8D-217A engines. In 1996, the Base opened an A340 maintenance workshop and sent 80 technicians to France for training.

Established in 1985, Shanghai Airlines, the first local airline in China, has ordered five additional Boeing 757-200 jetliners for delivery in 2004 and 2005. The new airplanes will bring the carrier's 757-200 fleet to 12 airplanes. In addition to the 757, Shanghai Airlines also operates Pratt-powered Boeing 767 aircraft. Based in Shanghai, China's largest city, the carrier operates a total of 23 Boeing airplanes and serves 100 routes connecting 54

Chinese cities and offering regional service to neighboring countries in Asia. Shanghai Airlines is majority-owned by the city of Shanghai and the local Jinjiang Group (a hotel cooperative). Shanghai Airlines perform maintenance on its fleet, and also plans to construct a hanger that can hold two large aircraft, which will be the only one in Pudong Airport.

3.1.3   Hong Kong Aircraft Engineering Co. Ltd. (HAECO): Location--Hong Kong

Based at Hong Kong International Airport, HAECO is the largest provider of airframe MRO services in the Asia-Pacific region. HAECO is well known throughout the aviation industry for its extensive capability on B747 and L1011 aircraft types including conversion programs of B747-200 combi to special freighter configurations. Over the years, HAECO Base Maintenance has also developed maintenance expertise on new generation aircraft such as Boeing B777 and Airbus A320/A321, A330 and A340 aircraft types and now offers comprehensive maintenance service package. In fact, C.G. Drury visited there in 1999 on a different project.

3.1.4   China Southwest Airline Maintenance Company & Sichuan, Snecma Aero-Engine Maintenance Co.: Location--Chengdu, Sichuan Province

China Southwest Airline Maintenance Company (CSAMC) which directly belongs to China Southwest Airlines, is a comprehensive maintenance base of Metric and British system airplanes, engines and their accessories. It was founded in 1965, and located in Chengdu Shuangliu International Airport. As one of the four engineering departments with CSAMC, Chengdu Maintenance Plant of China Southwest Airlines, located at Chengdu International Airport, is the airplane maintenance department of China Southwest Airlines' Chengdu base. It performs the tasks of line maintenance, periodic letter checks of all stages and categories and partial component overhaul for our fleet of B757, B737, TU154 and B707 airframes a total of 33 aircraft

Sichuan Snecma Aero-Engine Maintenance Co (SSAMC) was set up by Snecma Services and China Southwest Airlines set up in 1999. It supports CFM56 engines in service in China. Today, 51% of mainline jets (over 100 seats) operated by Chinese airlines (including those serving Macao and Hong Kong) are powered by CFM International engines, representing a fleet of nearly 800 CFM56 engines. SSAMC is ideally placed to exploit the potential of this market. SSAMC is certified MRO by Civil Aviation Administration of China (CACC). In 2001, SSAMC became the first Chinese firm to receive FAA certification for CFM56-3 engines. In 2003, SSAMC invested over $3 million in a cleaning and non-destructive testing line, making SSAMC China's only MRO facility capable of performing B3 maintenance on CFM56 engines.

Chengdu is a major Chinese aerospace center, located at the crossroads of future regional air transport routes, in a province that is currently benefiting from considerable economic expansion.

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3.1.5   Xinjiang Airline

Xinjiang Airlines maintains China's longest safe flight record of 48 years, which makes it China's safest airline (*People's Daily*, January 3, 2003).[10] Headquartered in Urumqi, capital of northwest China's Xinjiang Uygur Autonomous Region, the company owns 23 large and medium-sized passenger planes and has 86 domestic air routes and eight international routes. The company has wide experience in repairing and exploiting its diversified aircraft that include Boeing-757s, Boeing-737s, ATR-72s and II-86s.

3.2   Taiwan

Contacts with the ROC's Civil Aviation Authority have led to our contacting four sites in Taiwan for future visits. About five years ago, C. G. Drury was invited to visit one airline (Far Eastern Air Transport) to present a seminar to a number of airlines and the ROC's CAA. This has led to us being known in Taiwan, and should lead to cooperation even though the dates have not yet been finalized. The sites selected are all airlines, but they also perform maintenance on a third party basis. These represent four of the six airlines based in Taipei. All are in the Taipei area, at either

3.2.1 China Airlines

This airline operates 55 aircraft, split between Boeing and Airbus products. "It has a 2-bay and a 3-bay international standard maintenance hangars. These are the most advanced facilities in Asia, positioning China Airlines as a regional leader in aircraft maintenance services. Owing to its investment in state-of-the-art maintenance facilities, China Airlines meets the highest industry standards. It has received accreditations from the US Federal Aviation Administration and the European Joint Aviation Authorities, as well as an ISO-9002 certification. At home, it earned the National Laboratory accreditation certificate. These demonstrate China Airlines' commitment to maintenance standards." In 2001 it agreed to have a Singapore company, SIAEC restructure its Engineering and Maintenance Division. "The objective of the restructuring programme is to transform CAL's Engineering and Maintenance Division into an excellent maintenance, repair and overhaul (MRO) facility, as well as enhance CAL's aircraft maintenance quality and market competitiveness."

3.2.2 Mandarin Airlines

This a subsidiary of China Airlines, although all of its major operations are separate. Mandarin Airlines, serves about 15 domestic and international destination, with scheduled and chartered flights, and cargo services. In April 1996 they were granted the first ISO-9002 certification for service in Taiwan.

3.2.3 Far Eastern Air Transport Corporation

Their maintenance capability obtained recognition of ISO 9002 since 1996, and was certified by FAA on 2001. A quote from their CEO on the purchase of Pratt and Whitney

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engines recently was: "Far Eastern Air Transport, with 43 years in service, has continuously provided high quality in maintenance, flight operations, in-flight services," said Y. L. Lee, chairman of Far Eastern Air Transport. "This year, we're the recipient of Best Airline awards from the Civil Aeronautics Administration, especially in the area of maintenance quality with the strong support from Pratt & Whitney. We maintained above world average levels of dispatch reliability for more than a decade."

3.2.4 EVA Airways

This is Taiwan's second-largest carrier. With a number of other Taiwanese airlines they are beginning to undertake overhaul work on the world market.

4.0   Conclusions

In Year 2 we have taken the language error scenarios developed in Year 1, and used them as the basis for designing questionnaires to determine the frequency of these scenarios, how they can arise and what interventions are used to prevent the errors from propagating through the system. As we begin our data collection, we will use these questionnaires at each site we visit to build a comprehensive database for analysis in Year 3.

The Interventions experiment has also been designed and tested on two groups of participants: English-speaking maintenance personnel and Chinese speaking engineering graduate students. Neither is the final target group, but the methodology has been verified before on-site data collection. The main comprehension task takes less than half an hour to complete, while the other measures such as the Reading test and the rating scales together take another 15 minutes or so. Because many people can be tested together, we can be efficient in data collection at each site.

This experiment uses a baseline condition of English documents, and then adds translation (including the test form), a glossary, a bilingual coach, and a combination of these last two conditions. We are using two levels of task card difficulty, each with and without Simplified English. This makes a three factor factorial experiment (Intervention x Difficulty x Simplified English), with the Reading Level score as a covariate. On the samples tested so far, the US and UK participants obviously had the baseline intervention only, whereas the Chinese-speaking engineering students has all interventions. At this stage, the small sample sizes are precluding any significant effects, so these pilot studies are being used for testing the methodology, training the experimenters and providing an English-speaking baseline condition.

After having had one data collection visit cancelled, and encountering some difficulties with other foreign site post "9-11," we are now planning data collection using our contacts in China and Taiwan. Data collection at these sites will take place in March and April 2004, with any other sites coming in summer 2004.

5.0 Objectives for Year 3

To collect data on the frequency of Language errors and the effectiveness of coping strategies, we must visit foreign maintenance and inspection worksites. We are still finding this difficult in the current climate in aviation post "9-11." In Year 3 (February 2004 to August 2004) we will complete all of the data collection and analysis to meet the original objectives.

Original objectives for Phase II were to:

1. Better quantify the incidence of each type of language error identified in the taxonomy from Phase I.
2. Quantify the effectiveness of representative intervention strategies to reduce language-related errors.

Deliverables for Year 3 will be:

1. Report on the incidence if language-related error in aviation maintenance and inspection activities, and on the measured effectiveness of representative intervention strategies to reduce language-related errors.

2. Quarterly (December, March, July, and September) research progress status reports.

3. A paper will be submitted to the HFES annual meeting (New Orleans, October 2004) on the analysis of error data obtained so far, and of the results of initial data collection on error and recovery patterns. This will be entitled "Language-related errors in Aviation Maintenance"

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List of Acronyms

AECMA………………………Aircraft European Contractors Manufacturers Association

AIAA………………………..The **American Institute of Aeronautics and Astronautics**

AMECO…………………......**Aircraft Maintenance Engineering Co.,** Beijing, China

AMT……………………………………………………Aviation Maintenance Technician

ASRS…………………………………………The NASA **Aviation Safety Reporting System**

CACC……………………………………………..Civil Aviation Administration of China

CAMECO……………...Guangzhou Aircraft Engineering Co. Ltd., Guangzhou, China

CSAMC…………………………………China Southwest Airline Maintenance Company

FAA…………………………………………………The **Federal Aviation Administration**

GRE……………………………………………………...Graduate Record Examination

HAECO………………..**Hong Kong Aircraft Engineering Co**. Ltd., Hong Kong, China

JAA……………………………………………………………….Joint Aviation Authorities

MRO…………………………………………………………Maintenance, Repair & Overhaul

NASA………………………The US **National Aeronautics and Space Administration**

OEM……………………………………………………….Original Equipment Manufacture

PA……………………………………………………………………………..Public Address

SIA Engineering…………………………………………….Singapore Airline Engineering Co.

SASCO……………………………………….Singapore Technologies Aviation Service Co.

SSAMC……………………………………….Sichuan Snecma Aero-Engine Maintenance Co.

TAECO…………………...**Taikoo (Xiamen) Aircraft Engineering Co**., Xiamen, China

TOEFL…………………………………………….Test of English as a Foreign Language